

Durability of implanted electrodes and leads in an upper-limb neuroprosthesis

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Purpose of the Work. This study evaluated the durability and reliability of implanted leads and electrodes that are part of an implanted upper-limb neuroprosthesis. The neuroprosthesis provides grasping and reaching functions to individuals with cervical-level spinal cord injury (SCI).

Subjects and Procedures. Over 16 years, 27 subjects were studied. All subjects had sustained a traumatic SCI and were tetraplegic at the C5 or C6 motor level. All subjects had been implanted with an upper-limb neuroprosthesis.

Results. Our results indicate that the electrode, lead, and connector systems are extremely durable. We analyzed 238 electrodes that have been implanted as part of an upper-limb neuroprosthesis. Each electrode had been implanted at least 3 years, with a maximum implantation time of over 16 years. Only three electrode-lead failures and only one electrode infection occurred, for a survival rate of almost 99%. Electrode threshold measurements indicate that the electrode response is stable over time, with no evidence of electrode migration or continual encapsulation in any of the electrodes studied. **Relevance to the Veteran Population.**

Restoring function following paralysis is the primary goal of rehabilitation. Electrical activation of the paralyzed musculature is among the most promising modalities to accomplish this goal, especially for individuals with SCI. SCI is a debilitating and costly condition that is a major cause of extended and recurrent hospitalization. Basic grasp, bladder, bowel, and respiratory functions are being routinely restored to individuals with SCI through the application of neuroprostheses using electrical stimulation, which provide the paralyzed individual with a level of independence and quality of life that are unavailable through any alternative method. Neuroprostheses allow their users to return to more fulfilling lives in which individual performance is increased, thus eliminating many of the restrictions that impede more complete reintegration into societal roles. Our results impact the design of implantable neuroprosthetic systems. The electrode-lead component of these systems should no longer be considered a weak technological link.

Kevin L. Kilgore, PhD

Effects of regular use of neuromuscular electrical stimulation on tissue health

Kath M. Bogie, DPhil; Ronald J. Triolo, PhD

Purpose of the Work. This study investigated the hypothesis that chronic use of neuromuscular electrical stimulation (NMES) by individuals with spinal cord injury (SCI) will improve pressure distribution at the seating support area, specifically by reducing peak pressures over bony prominences because of increased muscle mass area. In addition, chronic NMES will increase vascularity, leading to improved tissue blood flow and resulting in improved regional tissue health in individuals with SCI.

Subjects and Procedures. Changes in tissue health were monitored in a group of eight SCI individuals using an implanted NMES system to provide standing and to facilitate standing transfers. Serial assessments were made of tissue oxygen levels in the ischial region, together with measurement of interface pressures at the seating support interface. **Results.** We found that unloaded tissue oxygen levels in the ischial region tended to increase after the individuals followed an NMES exercise program for 8 weeks. Concurrently, pressure distributions at the seating support interface tended to change such that, although the total pressure acting at the interface did not change, ischial region pressures showed a significant decrease.

Relevance to the Veteran Population. Veterans with SCI are at quite a high risk of developing pressure ulcers because of paralysis and immobilization. The results of this study indicate that chronic use of NMES has a quantifiable benefit on tissue health. Thus, this work is applicable directly to the health, well-being, and functional independence of the disabled veteran.

Kath M. Bogie, DPhil

Restoration of elbow extension via functional electrical stimulation in individuals with tetraplegia

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Michael W. Keith, MD

Purpose of the Work. This study evaluated the effect of electrical stimulation on the paralyzed triceps of individuals with tetraplegia, focusing on quantifying the increase in elbow extension strength and controllable workspace.

Subjects and Procedures. Measurements were made on 11 arms of individuals with cervical-level spinal cord injuries (SCIs). Elbow extension moments were measured at

different elbow angles, along with the number of successful trials and acquisition speed in moving an object to different positions in a workspace. **Results.** Stimulated elbow extension moments in 11 arms ranged from 0.8 to 13.3 N•m and varied with elbow angle. Elbow extension neuroprostheses provided statistically significant increases in the ability of an individual to successfully reach and move an object and significantly decreased the time required to acquire an object while reaching. **Relevance to the Veteran Population.** Addition of a triceps electrode to the neuroprosthetic hand grasps of veterans with SCIs can significantly increase their ability to extend their arms and increase their controllable workspace.

William D. Memberg, MS

Reliability and responsiveness of elbow trajectory tracking in chronic poststroke hemiparesis

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Purpose of the Work. This study established the reliability and responsiveness of a novel task for assessment of upper-limb perceptual motor control in hemiparetic adults. Successful performance of this type of task requires integration of perceptual cues, timing, and coordination of motor activity; thus, it is a sensitive indicator of altered motor performance, which occurs following stroke. Our goals were to determine (1) the reproducibility of this task in nondisabled and hemiparetic adults (reliability), (2) the magnitude of change necessary to conclude that clinically important effect had occurred (responsiveness), and (3) the requisite sample size for a clinical trial of upper-limb rehabilitation. **Subjects and Procedures.** Eleven persons with chronic poststroke hemiparesis (median 53 months) and eleven nondisabled controls performed an elbow trajectory-tracking task involving flexion and extension against a low-resistance isotonic load at three speeds: 25°/s, 45°/s, and 65°/s. Both arms (paretic and nonparetic or dominant and nondominant) were tested during two identical sessions separated by 1 week. The task goal was to match a criterion trajectory as closely as possible, minimizing the difference between the criterion and the subject's performed trajectory. Both nondisabled and hemiparetic subjects demonstrated reproducible performances on the trajectory-tracking task. However, because of greater trial-to-trial variability observed in both nonparetic and paretic arms,

smallest real difference scores were greater in hemiparetic subjects, indicating larger improvements must be demonstrated to conclude the efficacy of rehabilitative therapy.

Results. Our results suggest that with the use of this test of motor performance, 10 subjects per group will be sufficient to test the effectiveness of therapeutic intervention.

Relevance to the Veteran Population. Stroke is the leading cause of long-term disability in the Western world, involving over 600,000 new cases in the United States each year. Once people pass approximately the age of 55, their risk of stroke doubles with each decade of chronological age. The current median age of the veteran population is 58.8 years; by 2013, this cohort is projected to peak over 9 million veterans in excess of 65 years of age. Accordingly, strategies for development of efficient and effective rehabilitative interventions for stroke will remain a high priority in the healthcare management of veterans.

Carolynn Patten, PhD, PT

Improved upper-body endurance following a 12-week home exercise program for manual wheelchair users

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Purpose of the Work. This research was conducted to determine if a 12-week monitored home exercise program would improve cardiorespiratory endurance in a heterogeneous group of manual wheelchair users, which incorporated subsets of individuals with and without upper-limb impairment. **Subjects and Procedures.** Twenty-seven manual wheelchair users (20 without upper-limb impairment and 7 with upper-limb impairment) completed a 12-week home exercise program, which included biweekly visits to the laboratory to monitor progress and adherence. Maximum aerobic capacity and continuous exercise endurance tests were completed before training, at 6 weeks, and after completion of the exercise program. Results were evaluated for both pre- to posttraining changes in peak aerobic capacity and exercise endurance time, as well as for group differences in these parameters. **Results.** The training regimen resulted in no significant improvements in peak aerobic capacity. The regimen did, however, result in a substantial improvement in endurance on the constant work rate test. As expected, peak aerobic capacity was lower in the group with upper-limb impairment than in those without impairment at both baseline and after training. Endurance

on the constant work rate test was lower in the group with upper-limb impairment at baseline but seemed to improve to levels similar to those without upper-limb impairment by 12-weeks of training. **Relevance to the Veteran Population.** Many veterans are manual wheelchair users. The results of this study have determined that a home exercise training program that simulates propulsion movement can improve endurance in those with and without upper-limb impairment. The greatest benefits appear to occur in those who had upper-limb impairment. Improved endurance may reduce the likelihood of acquiring overuse injuries that could further impede ambulation in this population.

Randall E. Keyser, PhD

Informal care providers for veterans with SCI: Who are they and how are they doing?

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Purpose of the Work. This study determined the number of veterans with spinal cord injury (SCI) who rely on informal assistance to provide for their daily physical needs. It also described the characteristics of primary family care providers, assessed veterans' perceptions of the stability of their informal care networks in the future, and explored possible correlations of self-reported care and of perceived network instability. **Procedures.** Veterans with SCI who received care at the Houston VA Medical Center were interviewed by telephone. **Results.** More than a third of respondents reported receiving informal unpaid assistance with personal care activities. Primary informal caregivers provided more than 11 hours of care a day, on average. Nearly one third of veterans described their primary caregiver as being in only fair or poor health, and one-fourth reported that their primary caregiver was unlikely to be able to provide the same care for them 5 years from now. Most concerning, more than half stated that they did not have an alternate caregiver available if their primary caregiver became unable to care for them. **Relevance to the Veteran Population.** Our data confirm that informal family caregivers play an important role in the care of veterans with SCI. These data also highlight that not only veterans with SCI but also their informal care providers are aging. A breakdown in the informal caregiving network may contribute to increased secondary conditions and ultimately increased hospitalizations and nursing home placement of persons with

SCI. To prepare itself to provide effective care to veterans aging with SCI in the future and to anticipate the rapidly changing care needs of this population, the VA needs to examine informal care networks more closely.

Susan Robinson-Whelen, PhD

Quantitative comparison of plantar foot shapes under different weight-bearing conditions

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Purpose of the Work. This study quantifies the effects of weight bearing on the plantar foot shape. **Subjects and Procedures.** The plantar foot shapes of 16 normal feet were obtained by an impression-casting method under three weight-bearing conditions: non-weight bearing, semi-weight bearing, and full-weight bearing. Measurements and comparisons were made on the digitized foot shapes for the whole foot and selected regions. **Results.** The data showed that increased weight bearing significantly increased the contact area, foot length, and foot width, while at the same time decreasing average height, arch height, and arch angle. **Relevance to the Veteran Population.** Knowledge of the range of plantar foot shape alteration under weight bearing can offer implications for the design and construction of a comfortable and functional foot support.

Bonnie Yuk San Tsung, MPhil

Biomechanical analysis of cervical orthoses in flexion and extension: A comparison of cervical collars and cervical thoracic orthoses

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Purpose of the Work. Semirigid collars and cervical thoracic orthoses (CTOs) are used nonoperatively to protect the cervical spine after injuries and following surgical reconstruction. This study compared the efficacy of four contemporary cervical orthoses (Aspen collar, Miami J collar, Aspen 2-post CTO, and Aspen 4-post CTO) in limiting cervical spine motion in flexion and extension. **Subjects and Procedures.** Twenty normal volunteer subjects were tested in flexion and extension without any orthosis and with each of the four different cervical orthoses. The study quantified gross and segmental angular motion and

gross and segmental vertebral centroidal translation. The gross cervical motion was measured with an optoelectronic motion measurement system. Segmental motion was measured with low-dose, digital video fluoroscopy.

Results. All four orthoses significantly reduced gross and segmental cervical motion ($p < 0.05$). No significant difference was found between the Miami J and Aspen collars in restricting either gross or segmental motion. The CTOs were better than the collars in flexion-extension motion restriction, particularly at the lower cervical segments ($p < 0.05$). The 4-post CTO was more effective than the 2-post CTO in restricting extension motion ($p < 0.05$). **Relevance to the Veteran Population.** This study is aimed at significantly improving the quality of life of veterans suffering from cervical injuries and neck pain. The Department of

Veterans Affairs (VA) medical system is responsible for the care of a large number of veterans and family members with disorders of the cervical spine. We estimate that over 3,000 cervical collars were fitted in FY 2000 in the VA healthcare system nationwide. The findings of the study will help clinicians in selecting the optimum cervical orthosis for nonoperative and postoperative use based on the objective data on biomechanical performance of cervical orthoses. The selection of the optimum cervical orthosis would increase the veterans' likelihood of a good clinical outcome in nonoperative management of cervical disorders and would minimize postoperative complications and reduce the incidence of failed reconstructive procedures for cervical injuries and degenerative disorders.

Thomas M. Gavin, CO